such a drainage area. It amounts to a run-off depth of only 0.16 inch per hour. There are, however, two lakes in this basin, and the amount of stream channel storage is relatively large, so that from the same rainfall a run-off rate much larger would naturally be expected from the land area tributary to Bowman Pond.

Observers both at Sand Lake and Taborton state that 29 years ago, in August, roads were washed out and streams were slightly higher than on the recent occasion. Probably the intense rainfall of August 10 covered only the higher easterly portions of the Sand Lake Drainage Basin. (See fig. 3.)

CORRELATION OF WIND VELOCITY AND CONVECTIVE RAINS AT HOUSTON, TEX.

$55/.55 : 55/.578./ (764)$

By I. R. Tannehill, Observer.

[Weather Bureau, Houston, Tex., Apr. 16, 1921.]

SYNOPSIS

In the vicinity of Houston, Tex., convective rains are frequent during the summer months. These rains result from expansion and consequent cooling of air rising in a nearly vertical column. The air can not rise in a continuous convection column if the wind is of more than moderate velocity nor can it rise through or even well into a stratum of strong winds.

From a study of wind movement and rainfall at Houston, Tex., it is apparent that there is a strong relationship between these two elements. The lighter the surface wind movement the greater is the probability of local convective rains in summer.

In the vicinity of Houston there is sufficient moisture on nearly all days in summer; the necessary condition for the formation of convective rains is local heating in relatively quiet air.

The majority of the rains which occur at Houston, Tex., in summer are of a type peculiar to the territory bordering the Gulf of Mexico. The southeasterly monsoon is a source of abundant moisture on the coast. Toward the interior the rainfall diminishes. In other portions of the State the precipitation of this moisture may be due to cyclonic action or to forced ascent. In the coast section cyclonic disturbances in summer are limited mostly to rather infrequent tropical storms and since that section is practically flat, little of the rainfall can be ascribed to the forced ascent of air currents. Nearly all of the rains which do occur in the vicinity of Houston are undoubtedly convective in origin.

The strength of this southeasterly wind is variable. With the passage of high-pressure areas to the northward this monsoon becomes feeble and sometimes there occur distinct land and sea breezes. On a typical summer day, however, the southeasterly wind continues throughout the 24 hours, becoming stronger after midday. The formation of cumulus clouds is an almost daily occurrence. Yet day after day passes in summer with no rainfall at Houston if the southeasterly wind is strong.

On some days the convective column builds upward to great heights in quiet air. On other days the tops of the cumuli appear to be torn away and to dissolve on entering a stratum with a higher velocity of wind movement. It is obvious that a strong wind, by mixing unsaturated air with the air in the column, tends to prevent further growth of the cloud mass. Quiescence of the upper air is therefore an aid if it is not on some occasions essential to the formation of convectional columns to great altitudes.

Similarly, quiescence of the surface air favors the starting of convections, since it permits, as strong winds do not, appreciable local inequalities of temperature.

From observation it therefore appears that the prevailing southeasterly wind at Houston is productive of abundant rainfall when conditions are favorable for convection and that the important consideration is the strength of this southeasterly current.

Concerning convective rains, Prof. A. J. Henry, in Weather Forecasting in the United States, says:

There are two districts in which convective rains occur during the warm season. The first of the districts is along the Gulf coast, including the Florida peninsula, and extending back into the interior probably not more than 50 miles, the exact border not being as yet deter-

mined. Its east-west length is approximately 700 miles, or from the Atlantic in the neighborhood of Jacksonville. Fla., to about Houston, Tex. The pressure conditions associated with these rains are about as follows:

A high, with pressure 30.15 to 30.20 inches, overlies the southern portion of the middle Atlantic, with an extension over the Florida peninsula, in which the pressure is 30.08 to 30.10 inches. Pressure diminishes in a westerly direction to a region of indifferent gradients over southeastern Louisiana. The gradients are for gentle southeast winds along the coast and over the narrow fringe of the interior.

In the foregoing quotation it is pointed out that the pressure distribution is such as to give rise to gentle southeast winds.

The temperature of the air does not differ materially from one summer day to another in this section. On nearly all days there is an abundance of moisture. The important consideration seems to be the velocity of the southeast wind. When the wind is strong, rain is prevented by mixing, and the moisture is carried farther into the interior.

The records at Houston, Tex., covering a period of 11 years, 1910 to 1920, inclusive, were examined in an effort to determine any relationship that exists between rainfall and wind. During this period the anemometer and the rain gage have not been moved.

Table 1.—*Average wind velocity, miles per hour, and the number of rainy days, 0.01 inch or more, for each of the months June, July, and August.*

Year.	June.		July.		August.	
	Average wind movement (miles per hour).	Number of days with 0.01, or more, rainfall.	Average wind movement (miles per hour).	Number of days with 0.01, or more, rainfall.	Average wind movement (miles per hour).	Number of days with 0.01, or more, rainfall.
1910	7.4	9	7.4	11	7.1	6
1911	7.1	9	6.7	13	6.8	9
1912	8.5	9	6.3	12	6.9	11
1913	8.1	9	7.5	5	6.3	10
1914	6.7	7	6.7	5	6.7	18
1915	8.2	2	7.9	5	8.3	17
1916	8.3	7	5.9	13	6.6	14
1917	8.7	3	7.6	7	6.8	4
1918	6.9	5	6.7	6	6.6	9
1919	7.4	13	5.0	12	5.8	11
1920	6.7	10	6.1	12	5.5	17

For the values in Table 1, the coefficient of correlation [1] has been computed by the method of least squares. The equation used was

$$r = \frac{\Sigma(xy)}{\sqrt{\Sigma x^2 \Sigma y^2}}$$

for the correlation coefficient and

$$E_r = 0.674 \frac{1-r^2}{\sqrt{n}}$$

[1] See: The Effect of Weather upon the Yield of Corn, Mo. Weather Rev., Feb., 1914, 42: 78–87; also Elementary Notes on Least Squares, etc., ibid., Oct., 1914, 42: 551–568.

for the probable error of the coefficient, where x is the departure of wind velocity from its mean and y is the departure of number of rainy days from its mean.

From these data the coefficient is found to have the value -0.42 ± 0.10. This is a fairly high value. It will be noted that one unexpectedly large wind movement occurred in connection with a large number of rainy days in August, 1915. This value is shown at "A" in Fig. 1. This high wind movement was the result of the hurricane during that month. If that month's record is omitted the value of the coefficient of correlation is found to be -0.56 ± 0.08, in which the coefficient is seven times the probable error.

Because the influence of extratropical cyclones has not yet ceased in June, and because of the frequency of tropical storms in this vicinity in August, the coefficient
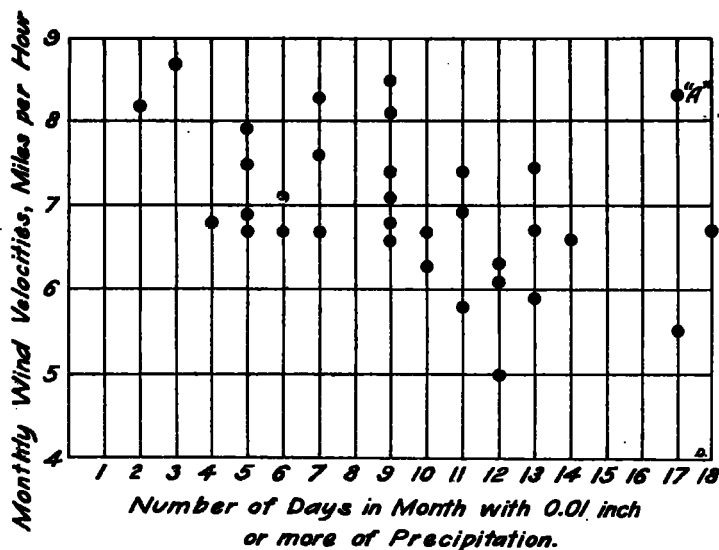

FIG. 1.—Relation between number of rainy days and wind movement in June, July, and August, 1910-1920, inclusive, at Houston, Tex.

of correlation has been computed for the month of July, for which the data are found in Table 1. The value for July is -0.65 ± 0.12, in which case the coefficient is higher and the probable error larger, which is to be expected.

TABLE 2.—Average wind velocity, miles per hour, for each year, 1910, to 1920, inclusive, and the annual number of rainy days for the same period.

Year.	Average annual wind.	Number of rainy days.	Year.	Average annual wind.	Number of rainy days.
	Mi./Hr.			Mi./Hr.	
1910	8.4	93	1916	8.4	87
1911	8.0	115	1917	8.6	69
1912	8.3	100	1918	8.2	93
1913	8.3	106	1919	7.7	126
1914	8.1	112	1920	8.2	113
1915	8.6	89			

From the values in Table 21 the coefficient of correlation is found to be -0.81 ± 0.07. This is positive assurance of a relationship, although the higher value is to be expected, on the assumption that there is such a relation, because of the longer period for which the averages were taken, being annual instead of monthly as in Table 1.

These values of the correlation coefficient [2] bear out the contention that the rains are more frequent in periods when the wind is light and also indicate that the season of convective rains sometimes extends into other months of the year.

TABLE 3.—Average daily wind movement, miles per hour, of July, 1910–1920, inclusive, for days with rainfall of 0.01 inch or more and for days with rainfall of 1 inch or more.

	Average hourly wind movement.
For all days	6.7 miles.
For days with rainfall, 0.01 inch or more	6.0 miles.
For days with rainfall, 1.00 inch or more	5.4 miles.

The averages in Table 3 prove beyond question that the wind movement is less rapid on rainy days and that the variation in the wind velocity is inversely proportional, to a certain extent, to the amount of rain.

The foregoing discussion is based upon surface wind movement. The wind in the lower levels of the atmosphere usually changes rapidly with altitude. The surface wind is not a reliable index to conditions aloft. If the above relation is true and it appears to have been established, it remains to study the relation between the wind aloft and the rainfall.[3]

With increasing height above ground the wind becomes more and more nearly constant. The wind at some distance above the surface is therefore a more reliable indication of the general air movements over the region in question. A knowledge of the wind aloft is therefore important.

CONCLUSION.

In the vicinity of Houston, Tex., where there is in summer abundant moisture and the temperature is persistently high, strong winds hinder the formation of local convective systems while any stagnant condition of the lower air is likely to produce frequent rains. A consideration of the general pressure distribution together with a study of wind movement aloft should enable the forecaster to predict convective rains with greater accuracy.

[2] In the Mo. WEATHER REV., Feb., 1914, 42: 79. Prof. J. Warren Smith says: "It probably is safest to assume that there may be some relation if the correlation coefficient is three times the probable error and that the relation is established beyond question if it is more than six times the probable error."
[3] The vertical temperature gradient is important but little is known concerning temperatures aloft at Houston during the convective rain season.